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An Evaluation of Aquatic Habitats at Edwards Air Force Base, California

Andrew C. Miller and Barry S. Payne

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Preface

Personnel at Edwards Air Force Base, Edwards, CA, are conducting floral and faunal surveys to determine the presence or absence of federally listed endangered or threatened species and to obtain information for an overall resource management plan. In the past they have conducted surveys for tortoises, birds, and eubranchipods (including tadpole, clam, and fairy shrimp). This report describes results of a survey for aquatic macroinvertebrates conducted in October 1995, March 1996, and May 1996. Field work, organism identification, and preliminary data analysis were done by Dr. David Beckett and B. Will Green, University of Southern Mississippi, Hattiesburg.

This report was prepared by Drs. Andrew C. Miller and Barry S. Payne, Aquatic Ecology Branch, Ecological Research Division, Environmental Laboratory (EL), Vicksburg, MS, U.S. Army Engineer Research and Development Center (ERDC).

During the conduct of this study, Dr. John Harrison was Director, EL; Dr. Conrad J. Kirby was Chief, Environmental Resources Division; and Dr. Edwin Theriot was Chief, Aquatic Ecology Branch. The point of contact for this work at Edwards Air Force Base was Ms. Wanda Deal.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston, and Commander was COL James S. Weller, EN.

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1 Introduction

Background

Edwards Air Force Base is located in the Mojave Desert in southern California near Los Angeles. With the exception of a few permanent ponds, the majority of water bodies at the base are dry during the summer. There are no permanent streams, and playas and most pools have few macrophytes. Terrestrial habitat consists of sand dunes, dry open hills, valleys, dry lakes or playas, smaller claypans, and pools. Vegetation surrounding playas is mainly saltbush scrub and around the pools and claypans is saltbush scrub, Joshua tree woodlands, cottonwood and willow thickets, and mesquite basque. The uplands are composed largely of creosote bush scrub (Branchiopod Research Group 1993; Pratt 1998).

Although aquatic habitats are limited at the base, they are an important component of ecosystem structure and function at the base. They are a source of water for migrating and local birds and terrestrial animals. Fairy shrimp, other crustaceans, immature insects, and worms live in the ponds and are a food source for other macroinvertebrates, fishes, and birds. Although these aquatic habitats represent a small percentage of available habitat at the base, it is likely that they are of benefit to terrestrial organisms. Availability of water for feeding and reproduction, presence of saltbush shrubs, insect prey of larger predaceous insects, and droppings of vertebrates that drink or feed from ponds probably can all be used by birds, reptiles, and certain terrestrial invertebrates. The habitat value of ponds on Edwards Air Force Base emanates not from an intrinsically rich or rare fauna within them. Rather, these ponds in an arid landscape add productivity, diversity, and complexity that support a rich and possibly rare terrestrial invertebrate fauna that otherwise could not exist.

Edwards Air Force Base personnel are conducting a series of floral and faunal surveys to check for federally listed endangered or threatened species and to obtain information for a complete resource management plan. Previous surveys have been conducted on tortoises, birds, and eubranchiopods (Branchiopod Research Group 1993). An intensive terrestrial invertebrate survey was initiated in 1996 (Pratt 1998). An analysis of aquatic habitats was initiated in 1995 because of the likely importance of these areas to the overall ecosystem.

Purpose and Scope

This report summarizes results of an invertebrate survey of aquatic habitats conducted at the Edwards Air Force Base, California, in October 1995 and March and May 1996. The purpose of the survey was to characterize the fauna of permanent and ephemeral aquatic habitats and to describe their role in the desert ecosystem.

2 Study Area and Methods

Study Area

Qualitative and quantitative samples were collected from Edwards Air Force Base on three separate dates--October 1995, March 1996, and May 1996 (Figure 1). Sampling sites were chosen based upon information provided by personnel at the base and data resulting from a terrestrial insect survey (Pratt 1998). In this report the large, single body of water in the southern portion of the base is referred to as Piute Pond, although it is generally called Piute Ponds by personnel at the base. Although there were islands within Piute Pond, it consisted of a single water body at the time of sampling.

The following habitats at the base were sampled on 5 October 1995 for invertebrates: Piute Pond, a pond near the sewage lagoon, and Branch Pond. On the second collecting trip, 27 and 28 March 1996, the following habitats were sampled for invertebrates: Piute Pond, pond near sewage lagoon, Branch Pond, Scout Road Pond, and four ephemeral ponds on Branch Memorial Road. On the final collecting trip, 29 and 30 May 1996, the following habitats were sampled for invertebrates: Piute Pond, pond near sewage lagoon, Branch Pond, and Scout Road Pond. Global Positioning System (GPS) coordinates for sites surveyed appear in Table 1, and Table 2 summarizes methods used at each location.

Methods

Temperature, specific conductance, and salinity were determined using a Yellow Springs Instruments Salinity-Conductivity-Temperature Meter. All data were collected in the field according to manufacturer's instructions.

A Petite Ponar grab sampler, which samples an area of 232.3 sq cm, was used to obtain quantitative sediment samples. Bottom sediments and the animals they contained were washed into a U.S. Standard No. 30 sieve bucket, which allowed the bottom particles to pass through while retaining the benthic (bottom-dwelling) macroinvertebrates. Sections of whole aquatic plants, or algal mats, were removed using scissors and placed in plastic zip-lock bags. Qualitative samples were obtained from some areas by sweeping a dip net over the bottom and among aquatic plants. All samples were preserved in 10 percent Formalin and stained with Rose Bengal (Mason and Yevich 1967) to facilitate separation of invertebrates from sediments and plant material.

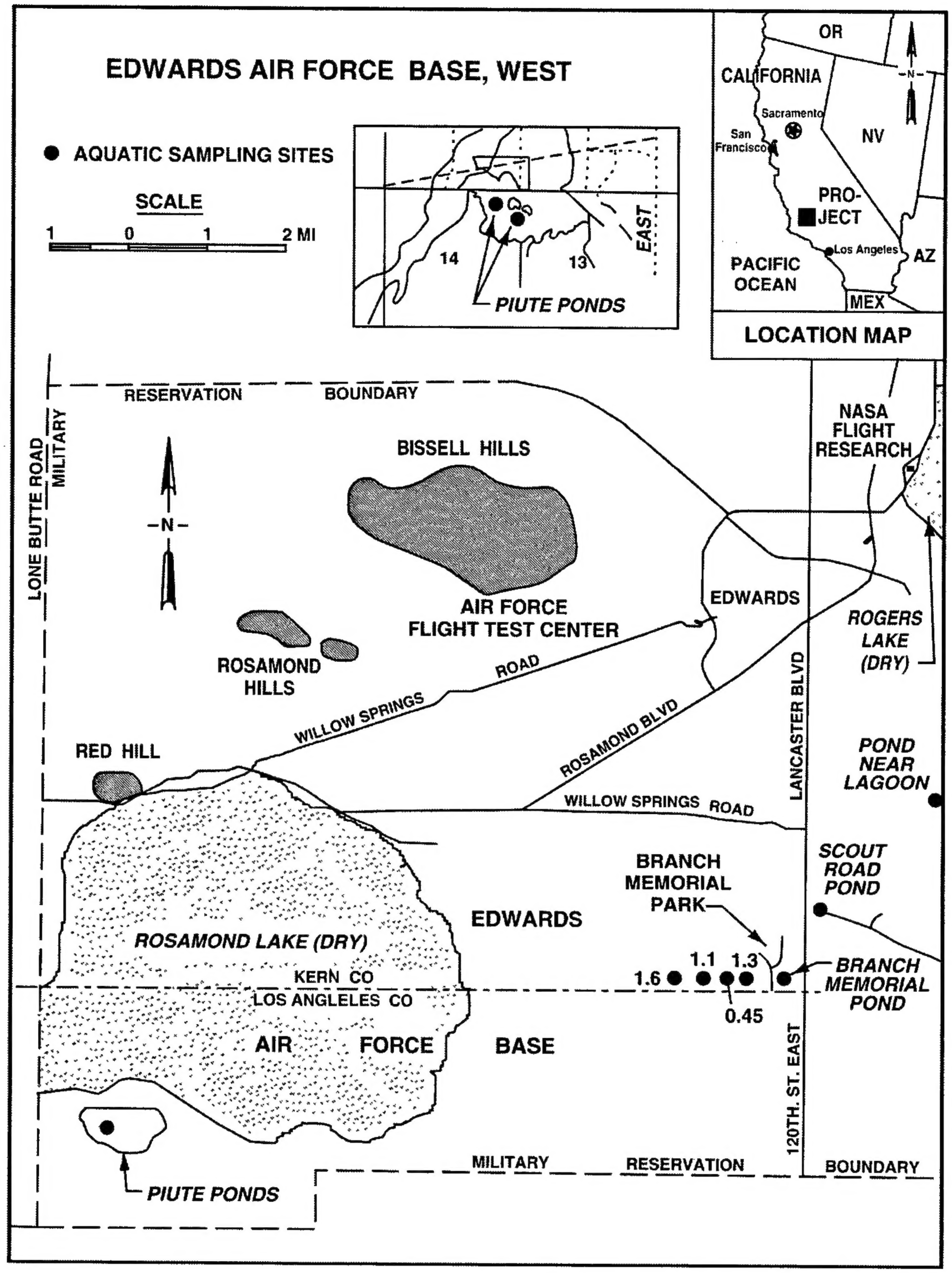

Figure 1. Aquatic study sites at Edwards Air Force Base

In the laboratory, sediments and plant material were placed in white, ceramic-coated aluminum trays. Organisms were removed while the material was viewed with a dissecting microscope at 6 × to 12 × power. After their removal, the oligochaete portion was subsampled, because of their overwhelming presence in many of the samples. The subsampling method consisted of collecting oligochaetes until approximately 100 to 200 individuals were obtained, 3 hr was reached, or the sample was completely sorted. Macroinvertebrates were then preserved in 70 percent ethyl alcohol and held in vials prior to identification.

Table 1
Coordinates Obtained from a Global Positioning System for Sites Sampled at Edwards Air Force Base, California

Site Name	Latitude (N)	Longitude (W)	Habitat Type
Piute Pond	34.791909	118.108397	Permanent
Pond near sewage lagoon	34.865279	117.881273	Permanent
Branch Pond	34.823645	117.923169	Permanent
Scout Road Pond	34.839572	117.91287	Ephemeral
Pond on Branch Memorial Road, 0.3 mile	34.822894	117.93327	Ephemeral
Pond on Branch Memorial Road, 0.45 mile	34.823045	117.937734	Ephemeral
Pond on Branch Memorial Road, 1.1 mile	34.822851	117.944214	Ephemeral
Pond on Branch Memorial Road, 1.6 mile	34.822701	117.95255	Ephemeral

Note: To convert miles to kilometers, multiply by 1.609.

Table 2
Location of Samples, Habitat Type, and Method Used for Macro-invertebrate Sampling, Edwards Air Force Base, 1995 and 1996

Location	Habitat Type	Method	Oct 95	Mar 96	May 96
Piute Pond	Rocks	Hand	x		x
	Middle	Petite Ponar	x	x	x
	Near island	Petite Ponar	x	x	x
	Cattails	Dip net	x	x	x
	Cattails	Cut stems		x	
	Algal mat	Dip net	x		x
Pond near sewage lagoon	Near shore	Petite Ponar	x	x	x
		Dip net	x	x	x
Branch Pond	Near shore	Petite Ponar	x	x	x
	Cattails	Dip net	x	x	x
		Cut stems	x	x	x
Scout Road Pond (Ephemeral pond)	Near shore	Petite Ponar		x	x
		Dip net		x	x
Ephemeral ponds	Near shore	Petite Ponar		x	
		Dip net		x	

Organisms were identified to species level where possible, and dry weights of major taxonomic groups were obtained. Dry weights were obtained by placing known quantities of the organisms in a drying oven at 105 °C for 1 hr, then into a desiccator for 1 hr, and finally weighing to four decimal places using a Mettler analytical balance. Larval chironomids and naidid worms were prepared for identification using the procedure of Beckett and Lewis (1982). The taxonomic nomenclature of Wiederholm (1983) was followed in the identification of larval chironomids. Oligochaetes were identified using the keys of Stimpson, Klemm, and Hiltunen (1985) (for Tubificidae), Hiltunen and Klemm (1985) (for Naididae), and Brinkhurst (1986) (for Tubificidae and Naididae). Branchiopods such as tadpole shrimp, clam shrimp, and fairy shrimp were identified using keys of Thorp and Covich (1991). The rest of the macroinvertebrates were identified using keys of Merritt and Cummings (1996) and Pennak (1989). Appendix A contains a complete list of all aquatic taxa collected at Edwards Air Force Base.

3 Results

Overview

Total macroinvertebrate density, based upon sediment samples taken with a Petite Ponar dredge, usually ranged from slightly more than 100 individuals/sq m to nearly 100,000 individuals/sq m (Figure 2). Piute Pond typically supported the greatest macroinvertebrate density, with higher values found in the fall than in spring or early summer. Four groups composed the majority of the macroinvertebrate taxa in permanent water habitats: the chironomids or true flies; the leeches; small crustaceans known as amphipods; and oligochaete worms. At Piute Pond the oligochaetes constituted more than 50 percent, by number, of the four most abundant groups present (Figure 3). Fewer numbers of macroinvertebrates were likely present in the spring and summer since typically these organisms emerge when temperatures increase.

The pond by the sewage treatment plant (STP) was virtually void of macroinvertebrates in October, although moderate- to high-density chironomid populations were found in March and May of 1996 (Figure 4). Lack of a dense and diverse assemblage of macroinvertebrates at this location is likely an indication of an effluent or some other stressor.

Macroinvertebrate densities in Branch Pond ranged from slightly more than 500 to nearly 3,500 individuals/sq m in March of 1996 (Figure 5). Densities in this pond were less than in Piute Pond, likely because this site was dredged earlier. The fauna was made up mainly of chironomids and oligochaete worms. The dominance of oligochaete worms over chironomids and the overall higher densities of these two groups in Piute Pond versus the other ponds are graphically illustrated in Figure 6.

Qualitative methods enable the investigator to obtain large numbers of organisms rather quickly from habitats that cannot be sampled using dredges or other quantitative devices. Amphipods dominated the qualitative collections in samples taken in October 1995 and May 1996 from the open water, rocks, algal mats, and cattails in Piute Pond (Figures 7 and 8). Fairy shrimp, tadpole shrimp, and clam shrimp were most abundant in ephemeral ponds (Figure 9). Branch Pond and Piute Pond, which are permanent, were dominated mainly by amphipods. The pond near the sewage treatment plant had low species abundance and was populated mainly by chironomids, backswimmers (Hemiptera), and a few microcrustaceans.

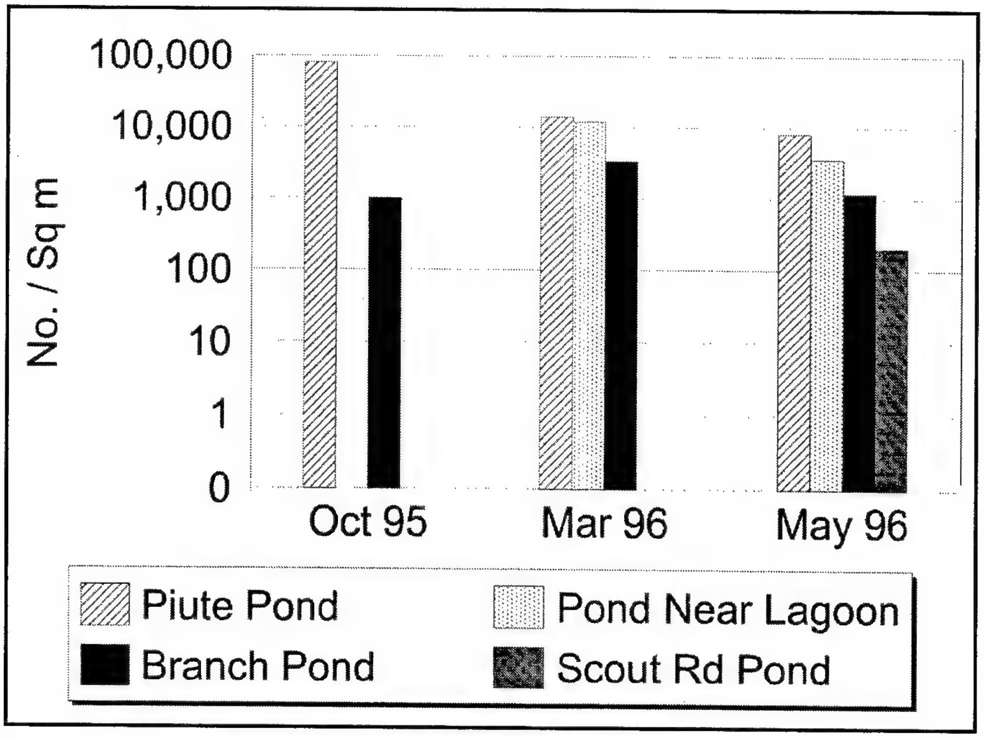

Figure 2. Total macroinvertebrate density at four habitats, three sampling dates, Edwards Air Force Base, California

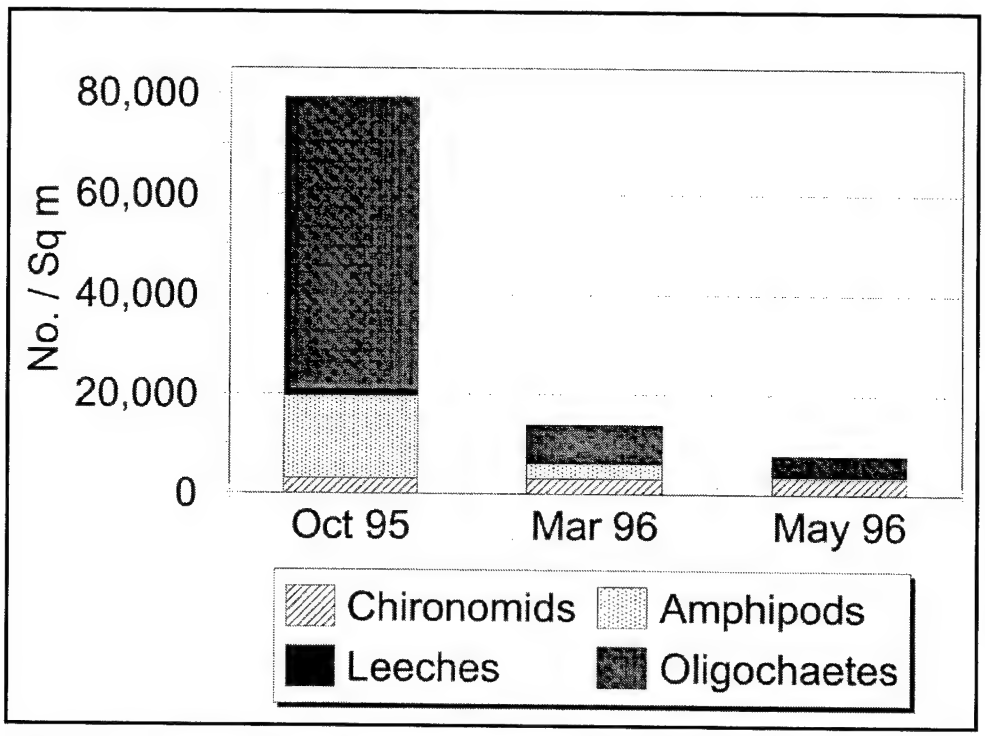

Figure 3. Density of major macroinvertebrate groups at Piute Pond, Edwards Air Force Base, California

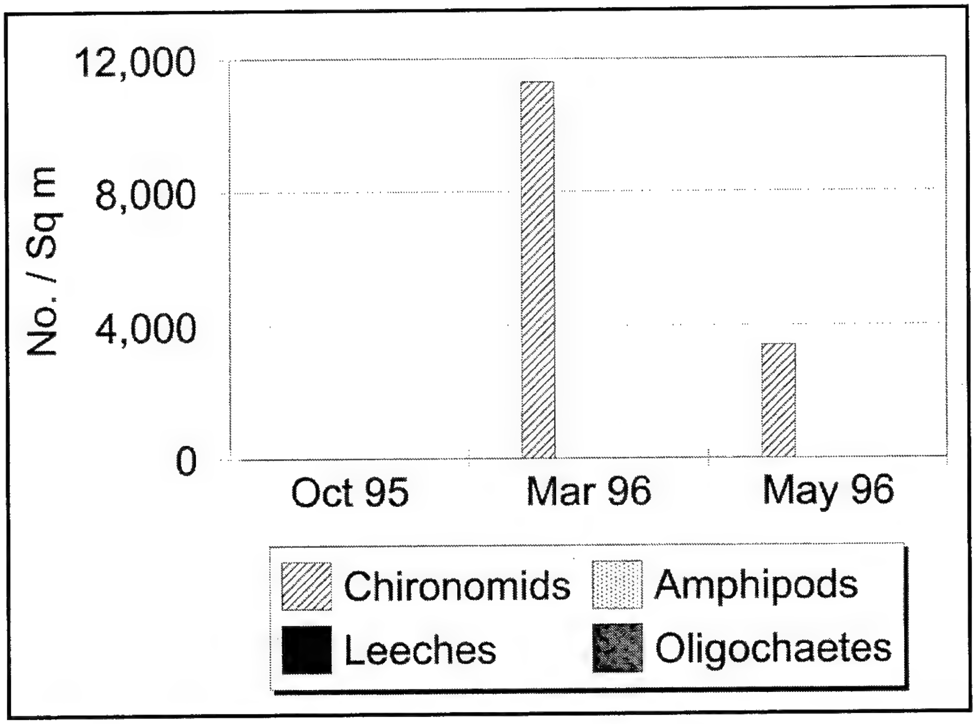

Figure 4. Density of major macroinvertebrate groups at a pond near a sewage lagoon, Edwards Air Force Base, California. No organisms were collected in October 1995

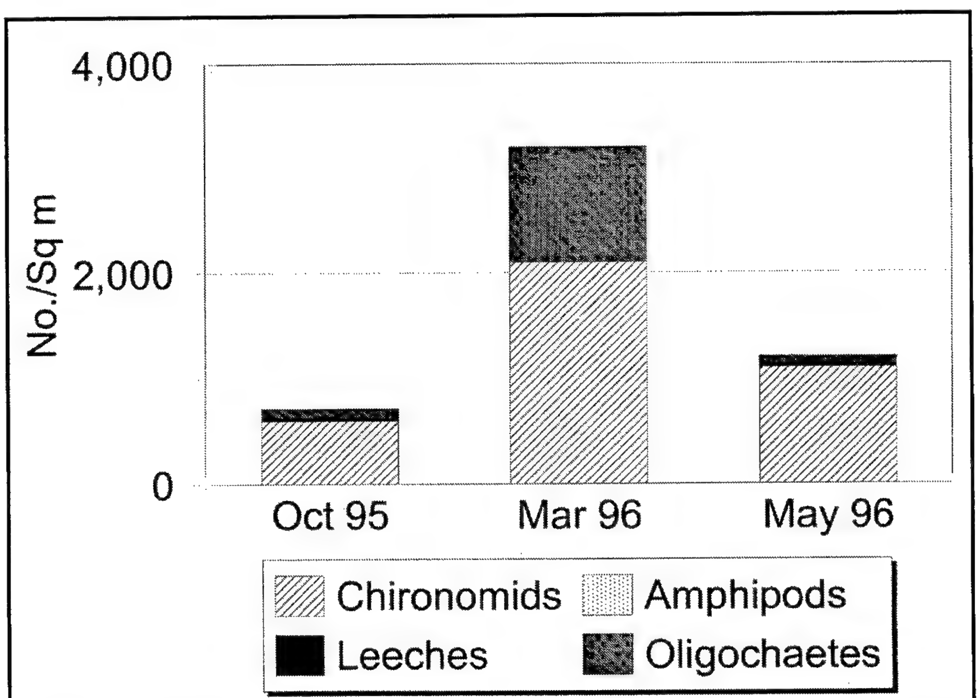

Figure 5. Density of major macroinvertebrate groups at Branch Pond, Edwards Air Force Base, California

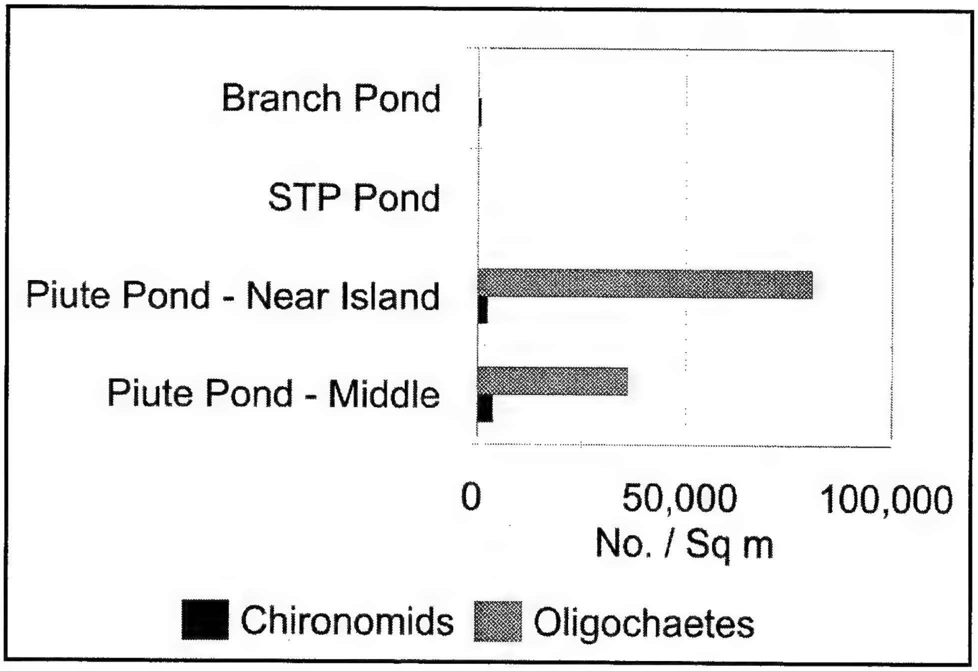

Figure 6. Density of chironomids and oligochaetes at four locations at Edwards Air Force Base, October 1995

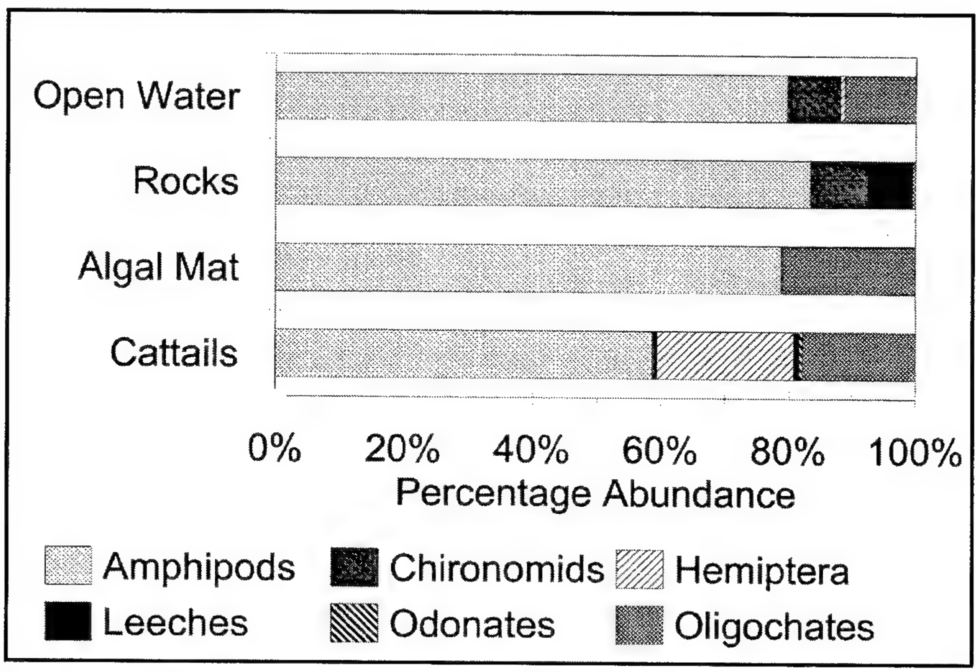

Figure 7. Percent abundance of major macroinvertebrate groups in Piute Pond, Edwards Air Force Base, October 1995

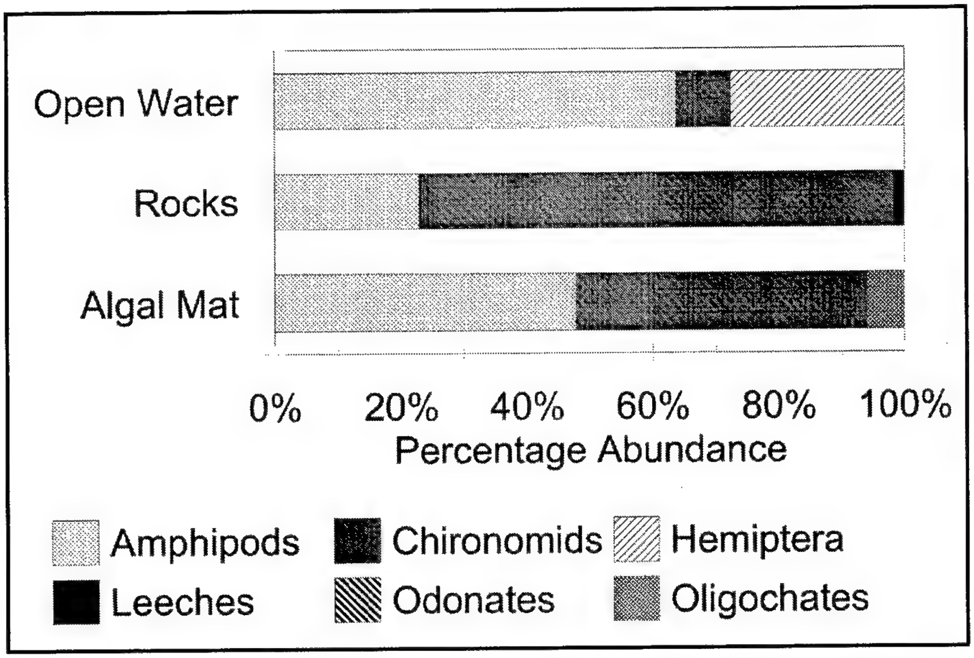

Figure 8. Percent abundance of major macroinvertebrate groups in Piute Pond, Edwards Air Force Base, May 1996

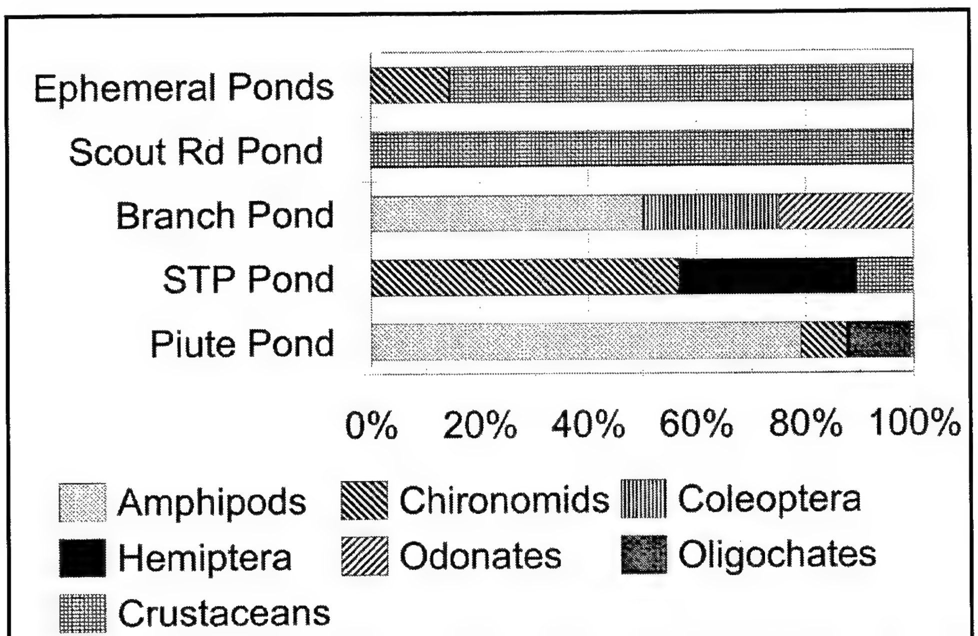

Figure 9. Percent abundance of major macroinvertebrate groups in Piute Pond, Edwards Air Force Base, March 1996

Description of Specific Habitat Types

Piute Pond

Rock samples were collected in very shallow water along the shore of Piute Pond. The surfaces of these rocks were inhabited by amphipods, chironomid larvae, leeches, oligochaetes, and a backswimmer. The amphipods were very abundant on the rocks with a mean density of approximately 28,000 amphipods/m^2 of rock surface. Chironomid larvae and leeches were also abundant (their mean densities equaled approximately 3,100 chironomids/m^2 and 2,800 leeches/m^2).

All of the amphipods on the rocks were members of the species *Hyalella azteca* (see Appendix A for a complete list of species names). This species is found throughout North America, including Canada, the United States, and Mexico, and is the most common and widely distributed North American freshwater amphipod (Bousfield 1958). All of the leeches in the samples were members of the species *Helobdella stagnalis*. Leeches, in general, have a reputation as bloodsuckers; however, many species of leeches are predators or scavengers, feeding mostly on other invertebrates, rather than acting as parasites (Pennak 1989; Klemm 1991). *Helobdella stagnalis* is one of the predatory leeches, feeding on aquatic invertebrates (i.e., it does not suck blood). Among its prey are oligochaetes, chironomids, and amphipods (Klemm 1991), all of which were also present on the shoreline rocks in Piute Pond. *Helobdella stagnalis* is a cosmopolitan, worldwide species, found on every continent except Australia (Klemm 1991).

All of the chironomid larvae (Insecta: order Diptera (the true flies); family Chironomidae) on the Piute Pond rocks belonged to the genus *Glyptotendipes*. Pinder and Reiss (1983) separate the genus into three groups: A, B, and C. The larvae in Piute Pond belong to the Species Group A, which is the equivalent of the subgenus *Phytotendipes*. Larvae of Species Group A live predominantly in littoral (shoreline) sediments of lakes and ponds or in the *Aufwuchs* (which consists of both flora and fauna attached to submerged objects such as rocks, logs, sticks, and vegetation). The few oligochaetes (oligochaetes are members of the class Oligochaeta within the phylum Annelida, the segmented worms) present on the rocks collected near the shore were immature members of the family Tubificidae. The backswimmer (order Hemiptera: family Notonectidae) belonged to the genus *Buenoa*. Backswimmers are predators and feed on small crustaceans, insect larvae, snails, small fish, and terrestrial insects that may fall into the water (Sanderson 1982).

Petite Ponar samples were taken from near the middle of Piute Pond during the three seasons. Oligochaete worms (primarily in the family Tubificidae, called tubificids) were the most abundant macroinvertebrates in the lake bottom, followed by insect larvae in the family Chironomidae (chironomids). Two species of tubificid oligochaetes were abundant in the bottom of the pond: *Limnodrilus hoffmeisteri* and *Potamothrix bavaricus*. *Limnodrilus hoffmeisteri* is a ubiquitous species and is probably the most abundant and widespread tubificid

worm in North America (Stimpson, Klemm, and Hiltunen 1985). *Potamothrix bavaricus* is a Holarctic species (from North America, Europe, and northern Asia), but is relatively uncommon. It has been reported from Utah, California, and Oklahoma in the western United States (Stimpson, Klemm, and Hiltunen 1985). Numerous immature tubificid oligochaetes without capilliform chaetae were collected in the grabs from the bottom of the pond; these were probably immature *L. hoffmeisteri*. An oligochaete species belonging to the family Naididae was also collected. This species, *Dero digitata*, was much less common than *L. hoffmeisteri* or *P. bavaricus* in the bottom substrates of the pond.

The chironomid larvae in the bottom of Piute Pond belonged to three taxa: *Chironomus* sp., *Procladius* sp., and *Tanypus* near *grodhausi*. All three of these taxa were found in each of the three grabs. The genus *Chironomus* contains a large number of species (several hundred according to Pinder and Reiss (1983)), and it is not possible to identify the Piute Pond larvae beyond the genus level. The larvae of *Chironomus* occur in many types of freshwater habitats, although they are found more commonly in still water and slower areas of flowing waters (Oliver and Roussel 1983). Some species of *Chironomus* can tolerate low dissolved oxygen.

Procladius is predaceous as a larva. Members of this genus are usually found in muddy substrates in standing or slowly flowing waters (Fittkau and Roback 1983); the *Procladius* in Piute Pond were found in such a habitat. Fittkau and Roback (1983) divide the *Procladius* into two subgenera, *Holotanypus* and *Psilotanypus*. The larvae in Piute Pond are members of the subgenera *Holotanypus*. The third chironomid taxon found in the bottom of the pond was a species of *Tanypus*. Members of this genus are found in fine-grained sediments in ponds or in pondlike conditions. The larval *Tanypus* found in Piute Pond key out in Roback (1977) to *T. grodhausi* Sublette or *T. nubifer* Coquillett. This report designates this species as *Tanypus* nr. *grodhausi*.

The leech species found on the rocks near the edge of Piute Pond (*H. stagnalis*) was present in the bottom of Piute Pond as well, although in densities much less than on the harder substratum. Mean *H. stagnalis* density in the lake bottom was 186.6 individuals/m^2. One of the grab samples also contained three amphipods (*H. azteca*), and another contained one backswimmer in the genus *Buenoa*.

The tubificid composition in Piute Pond near a small island was very similar to that of the bottom samples from the middle of the pond; i.e., the same two species were present: *L. hoffmeisteri* and *P. bavaricus*. The naidid worm *D. digitata* was also present in these bottom substrates (as it was in the deeper water in the middle of the pond). The larval chironomid composition at this location was similar to that found near the middle of the pond. The same three taxa, *Chironomus* sp., *Tanypus* nr. *grodhausi*, and *Procladius* sp., were present.

Large numbers of the amphipod *H. azteca* were present on the bottom substrates near the island. Mean density of this species was 36,339 amphipods/m^2 of lake bottom. The leech *H. stagnalis* was also fairly abundant near the island and had a mean density of 2,081 leeches/m^2. This was approximately 11 times the

mean density of leeches found in the bottom substrates in the middle of Piute Pond.

A few early-instar (early stages) water boatman nymphs (in the insect order Hemiptera (true bugs), family Corixidae) and one male adult (genus *Corisella*) were present. Water boatmen feed on fine-grained sediments (Sanderson 1982), gathering their food by sweeping the flocculent materials from the bottom into their mouths using their first legs. One backswimmer, a member of the genus *Buenoa,* was also collected.

A qualitative sample was taken from cattails near the island by sweeping a net through the cattails and across the bottom of the pond. The sample contained large numbers of tubificid worms and amphipods (*H. azteca*), along with some leeches (*H. stagnalis*). These species were also present in large numbers in other samples from Piute Pond. However, the qualitative sample also contained a few species not present in the other samples. Four nymphs and one adult backswimmer, all in the genus *Notonecta*, were present. One mosquito larva in the genus *Anopheles* and snails in the genus *Physella* were also in the qualitative sample.

Large numbers of corixid (water boatmen) adults and nymphs were present in the qualitative sample. All of the corixids were members of the genus *Corisella*; the adult males (the only group within the genus for which a key exists) were members of the species *Corisella inscripta.* Usinger (1974) states that this species is found in the western United States, including southern and central California, and Mexico, and is tolerant of saline waters. One very immature dragonfly nymph and one very immature damselfly nymph (family Coenagrionidae) were also present.

Samples were taken from an algal mat on the surface of Piute Pond near the island. Two taxa were abundant in these samples: the amphipod *H. azteca* and the naidid worm *Pristina leidyi.* Since many worms were present within the mat, a large number of them were examined to determine if more than one species was present. All of the worms proved to be *P. leidyi.* Several springtails (Insecta: order Collembola) were present in the algal samples as well. One adult and several larvae of the beetle family Hydraenidae, the minute moss beetles (genus *Ochthebius*) were collected. These beetles are very small (ca. 1-2 mm in length) and live near the surface of the water.

Pond near the sewage lagoon

No benthic macroinvertebrates were found in the Ponar grabs at this location. The qualitative collection using a dip net yielded 11 water boatman (Hemiptera), all members of the genus *Corisella.*

Branch Pond

The bottom fauna of this pond consisted of chironomid larvae and oligochaetes; however, neither was abundant. Mean oligochaete density in Branch Pond was much less than mean oligochaete densities in the middle of Piute Pond and near the island of Piute Pond (Figure 6). Similarly, mean larval chironomid

density in the bottom of Branch Pond was less than the mean larval chironomid densities in the middle of Piute Pond and near the island. The chironomid larvae in the bottom of the pond were members of the genera *Chironomus*, *Procladius*, and *Tanypus*. All three of these genera were also present in the bottom of Piute Pond. However, all of the larval *Tanypus* in the bottom of Branch Pond were members of the species *T. stellatus*; in Piute Pond all of the larval *Tanypus* were members of the species *Tanypus* nr. *grodhausi*. Two species of oligochaetes were present in the bottom of Branch Pond: *P. bavaricus* and *D. digitata*.

In addition to the bottom of the pond, the submerged portions of the cattails in the littoral area of Branch Pond provided habitat for epibenthic macroinvertebrates (living on the surface of objects, rather than burrowing down into the substrates). Portions of these cattails were clipped and examined for macroinvertebrates. Among the invertebrates on the cattails were 1 chironomid larva and 11 oligochaetes. The chironomid larva and the oligochaetes were members of taxa that had not been collected in any previous samples. The chironomid larva belonged to the *Cricotopus sylvestris* group (a group of species similar to *C. sylvestris;* these species cannot be separated as larvae); the oligochaetes were members of the species *Nais variabilis*. *Nais variabilis* is widespread and is one of the most common naidids (family Naididae) in North American freshwater habitats (Hiltunen and Klemm (1985).

Caddis fly larvae (Insecta: order Trichoptera, genus *Oxyethira*) were also present on the cattails and were the only caddis flies found among the samples at the base. This genus is a member of the family Hydroptilidae, the microcaddisflies, so called because many of the members of this family are very small, reaching a length of only 2 to 3 mm. *Oxyethira* make flattened, bottle-shaped cases consisting entirely of silk. A dragonfly nymph was also present on the cattails, but was too small to identify.

Two species of snails were present on the cattails. An individual belonging to the genus *Physella* (family Physidae) was present, as were three snails belonging to the family Planorbidae. All three of the planorbids appeared to be members of the same species. However, all of the specimens were small and immature and could not be identified below the family level. Three flatworms were present on the cattail sample. These flatworms were planarians, and were members of the species *Dugesia tigrina*. This species of planarian is common and widely distributed (Kenk 1976).

Forty small damselfly nymphs were collected using a dip net in the cattails. The damselflies are related to the dragonflies; dragonflies and damselflies are members of the same order but constitute different suborders. It was possible to determine that the relatively larger damselfly specimens were all members of the family Coenagrionidae and belonged to the *Enallagma, Coenagrion, Ischnura* complex. An approximately equal number of very small dragonfly nymphs were also collected. Based on the prementum (a mouthpart) it was clear that at least two species of dragonflies were present on Branch Pond cattails since some of the nymphs were members of the Libellullidae/Corduliidae (two similar families) whereas others were members of the Gomphidae/Aeschnidae (two other dragonfly families).

One amphipod was present in the qualitative dip net sample. It was a member of *H. azteca*, which was so abundant in Piute Pond. More caddis flies in the genus *Oxyethira* and a very small planorbid snail were also collected using the dip net.

Ephemeral ponds

Although a notable feature at the base, the ephemeral ponds or clay pans would provide a greater benefit to most aquatic biota if they remained wet for a greater part of the year. However, the ponds do provide habitat for crustaceans, notably including tadpole, clam, and fairy shrimp, and some immature flies (chironomids). The larger crustaceans and recently emerged chironomid flies provide a source of food for wading and shore birds during late winter and early spring. Although biota would be limited to some extent by high temperatures, lack of appropriate substratum, and high salinity, the major limiting factor would be the fact that the ponds are in existence for a short portion of the year. The pond on Scout Road was also an ephemeral pond.

Seasonal Considerations

Most macroinvertebrate studies are designed so that organisms are usually collected during at least two seasons: spring and fall. If samples are collected too late in the spring, many macroinvertebrates have already emerged and densities can be low. Fall samples typically yield a large number of nearly mature organisms that are easily collected and identified. The highest macroinvertebrate density, nearly 100,000 organisms/sq m, was recorded at Piute Pond during October 1995. In early and late spring, total densities were approximately one tenth this value, less than 10,000 organisms/sq m. This was likely the result of emergence of maturing chironomids, which represented a large percentage of the numerical density. To some extent reduced densities in the spring can also be caused by large numbers of immature oligochaetes and crustaceans that are simply too small to collect or to identify.

Water Quality

Salinity, specific conductance, and water temperature revealed little seasonal variability at the base (Table 3). Although specific conductance was high in some ponds, revealing elevated ionic concentrations, these values were not high enough to limit macroinvertebrate distribution and abundance.

Macroinvertebrates are typically used to monitor changes in water quality. Two metrics often used to monitor macroinvertebrates are taxa richness and a variation of that called EPT richness (Ephemeroptera, Plecoptera, and Trichoptera) (Merritt and Cummings 1996). While these metrics are most often applied to lotic water situations such as rivers and streams, they can also be used for aquatic habitats at EAB.

Table 3
Temperature, Specific Conductance, and Salinity for Piute Pond, Branch Pond, and the Pond Near the Sewage Lagoon at Edwards Air Force Base

Location	Time	Temperature °C	Conductance mhos/cm	Salinity mg/
Date: 5 Oct 95				
Piute Pond	1000	16.5	2,320	1.5
Branch Pond	1430	20.5	360	0.0
Pond near sewage lagoon	1630	21.5	1,390	0.8
Date: 28 Mar 1996				
Piute Pond	0900	15.0	1,920	1.1
Branch Pond	1230	19.5	306	0.0
Pond near sewage lagoon	1330	20.5	1,210	0.7
Date: 30 May 1996				
Piute Pond	0945	19.5	2,250	1.4
Branch Pond	1400	22.0	345	0.0
Pond near sewage lagoon	1530	23.5	1,210	0.9

The taxa richness metric is based on the assumption that the number of taxa will decrease as water quality declines. As expected, the organically polluted pond by the sewage lagoon had substantially decreased numbers of taxa compared with the other ponds on the base. The macroinvertebrate communities in the pond by the sewage lagoon comprised only pollution-tolerant chironomids and tubificid worms, or on one sample date, just a semiaquatic genus of Hemipterans. Also, by comparison, the other ponds had such organisms as amphipods, cladocerans, and odonates, which tend to be ubiquitous to freshwater habitats that range from acceptable to good quality.

The EPT richness metric is based on the observation that most taxa in these three orders are sensitive to pollution. While the number of EPT organisms found in the ponds were low, the presence of Trichoptera in Branch Pond on two sampling dates and Ephemeroptera in Piute Pond indicates that water quality is good enough in these two ponds at some time during the year to support these pollution-sensitive organisms.

4 Discussion

Value of Selected Habitats at Edwards Air Force Base

Pratt (1998) reported especially high richness of terrestrial invertebrate species at sites adjacent to Branch Memorial Park Pond (362 species at his Site 1a) and Piute Pond (293 at his Site 3b). Furthermore, 27 percent and 35 percent of the species he found at his Sites 1a and 3b, respectively, were obtained only at those particular locations. Thus, permanent ponds, a rare habitat, were associated with high terrestrial species richness and occurrence of possibly endemic species. Factors including availability of water, saltbush shrubs, insect prey of larger predaceous insects, and droppings of vertebrates that drink or feed from ponds probably supported the high terrestrial invertebrate richness.

Despite richness in the terrestrial community, ponds supported a simple aquatic invertebrate community. In Piute Pond, which had not been recently drained, invertebrate biomass was dominated in October by two ubiquitous species: the amphipod *H. azteca* and the leech *H. stagnalis*. Numerically abundant but smaller oligochaetes and chironomids were also dominated by relatively ubiquitous taxa. Although ponds are a rare feature that add considerable habitat complexity to the terrestrial landscape, habitat within ponds is relatively simple. In addition, invertebrates in desert ponds must tolerate stressful conditions including moderately high water temperature and slightly brackish water. Thus, it is logical that the aquatic community is relatively simple and dominated by tolerant taxa.

Similar dominance by an amphipod and a leech was noted for the aquatic invertebrate community of Montezuma Well, an artesian pond in the northern Sonoran Desert (Blinn, Wagner, and Grim 1986; Davies, Singhal, and Blinn 1985). The food web of Montezuma Well (void of fishes) consisted of an abundant and endemic pelagic amphipod (*Hyalella montezuma*) that was the principal prey item of an endemic leech (*Erpobdella montezuma*). Indeed, the leech in that system showed a distinct noctural migration determined by the behavior of the nocturnally active amphipod. The average leech consumed 10-14 amphipods each evening; leeches captured amphipods by swimming after them. Although an endemic fauna was lacking, the high abundance of the amphipod *H. azteca* and the leech *H. stagnalis* in the Piute Ponds of Edwards Air Force Base in October suggested the possibility of a similar food web.

Nocturnal activity of the dominant invertebrates in desert ponds is potentially adaptive in at least two ways. First, remaining inactive and hidden among

bottom debris during the day probably reduces predation by sight-feeding vertebrates (e.g., fish, turtles, and birds). Second, remaining under debris and partially buried in bottom sediments may provide leeches and amphipods some refuge from stressfully warm water during the day.

Compared to terrestrial habitat, ponds on Edwards Air Force Base are few and relatively simple. Thorough sampling of invertebrates dwelling in the ponds revealed a simply structured community of mostly ubiquitous species, but a very productive community. Considered alone, this result suggests that ponds are not an especially valuable habitat with respect to invertebrate diversity. However, ponds in the desert are unmistakably special in a landscape context. Only when terrestrial invertebrate reliance on permanent ponds is considered is the special habitat value of ponds revealed.

Thus, the habitat value of ponds on Edwards Air Force Base emanates not from an intrinsically rich or rare fauna within them. Rather, these ponds in an arid landscape add productivity, diversity, and complexity that support a rich and possibly rare terrestrial invertebrate fauna that otherwise could not exist. It should be cautioned that compared to the size of the base, comparatively few samples and sites were studied over a brief period of time. Regardless, the value of these aquatic habitats cannot be ignored.

Major Findings

Macroinvertebrate communities reflected substratum type and the relative permanency of aquatic conditions. Among permanent ponds, the Piute Pond sampled, not having been drained recently nor affected by effluents, supported a more mature and diverse aquatic invertebrate fauna than either Branch Pond or the pond near the sewage treatment plant. Thus, Piute Pond probably best reflected realized habitat potential.

The rocks near the shore of Piute Pond were densely colonized by invertebrates, especially by amphipods, chironomid larvae, and leeches. All of the chironomids were members of the genus *Glyptotendipes*. This species was not found on other substrates in Piute Pond. The leeches on the rocks near the shoreline of Piute Pond were all members of the species *H. stagnalis*, a predaceous leech that feeds on aquatic invertebrates; *H. stagnalis* is not parasitic. Amphipods (all *H. azteca*) and leeches were also abundant on the bottom of Piute Pond in shallow water near an island. The community compositions of the bottom-dwelling invertebrates in the middle of the pond and in shallow water near the island were similar. The same three oligochaete species and same three chironomid species were found in each habitat. However, the densities of leeches and amphipods, which were found in such high numbers near the shore, were much lower in the deeper waters of Piute Pond.

There are only two widespread genera of backswimmers in North America, *Notonecta* and *Buenoa*. Both genera were present in Piute Pond. Snails, a dragonfly nymph, and a damselfly nymph were found among the cattails, as were large numbers of the backswimmer *C. inscripta*. Floating mats of algae near an island in the pond were colonized by amphipods and the ubiquitous naidid worm

P. leidyi. This worm species, often associated with filamentous algae, was not found in any of the other habitats at Piute Pond.

Although the bottom infauna of Branch Pond was dominated by oligochaetes and chironomid larvae, as was Piute Pond, densities in the former were only a fraction of those in Piute Pond. Although the same three genera of chironomids were found in the bottom substrates of both ponds, *Tanypus* nr. *grodhausi* was found in Piute Pond whereas *T. stellatus* was present in Branch Pond. Caddis fly larvae in the genus *Oxyethira* and damselfly and dragonfly nymphs were also found on cattails of Branch Pond. The waters of Branch Pond were less saline than those of Piute Pond or the pond near the sewage lagoon (Table 3). The reduced benthic invertebrate densities in the bottom of Branch Pond were probably due to the periodic draining of the pond. A fisherman at Branch Pond mentioned that the pond was drained periodically, and had been drained in June of 1995 and then refilled about 4 months prior to sampling.

No invertebrates were present in the bottom samples from the pond near the sewage lagoon although water boatmen (members of the genus *Corisella*) were present. It is likely that this pond had been recently drained or had received an effluent that had eliminated the bottom-dwelling invertebrates.

Piute Pond had not been recently drained; the invertebrate fauna represented a relatively stable aquatic community. Oligochaetes and amphipods dominated Piute Pond, and chironomids and leeches were abundant. Of these abundant taxa, only chironomids easily disperse (when adults emerge and fly). Notably, chironomids dominated both Branch Pond and the pond near the sewage treatment plant. Oligochaetes, amphipods, and leeches are entirely aquatic and not especially tolerant of desiccation. The dominance of these purely aquatic taxa reflects the relative permanence of aquatic conditions at the Piute Pond.

Vernal pools were dominated by taxa specially adapted to brackish and very temporary aquatic habitats (Figure 9). *Branchinecta* (fairy shrimp), *Lepidurus* (tadpole shrimp), and *Caenestheriella* sp. (clam shrimp) were dominant. The high density and extraordinarily rapid growth of taxa in vernal pools is possible due to the lack of any fish or large invertebrate predators or competitors for food in these ecosystems. *Branchinecta* and *Lepidurus* must feed virtually continuously to attain the large body mass they achieve within a brief aquatic life of only 2-3 months. In addition, these vernal pool species tolerate brackish conditions and produce eggs capable of withstanding, and in some cases requiring, long periods of dry conditions. Invertebrate inhabitants of permanent ponds do not share these characteristics. The productivity of vernal pools, while unexploited by predators within the pool ecosystem itself, may be exploited by wading birds.

Aquatic Habitats

Aquatic habitats are a unique resource at Edwards Air Force Base, representing less than 1 percent of the area of the terrestrial habitat. Most aquatic habitats are ephemeral, existing for only a few months. Permanent water bodies consist of Branch Pond, located in Branch Memorial Park, and the Piute Ponds, all located on the western part of the base. In comparison with Piute Ponds, Branch

Pond has extremely low macroinvertebrate density and species richness, probably because it was drained and dredged 4 months prior to this survey. Density and diversity of aquatic invertebrates would be greater in Branch Pond if it were not drained so often. The increase in invertebrates would also provide an increased food source for the fishes in the pond. Density and species richness of aquatic insects in the permanent ponds would be greater if there were larger rivers, lakes, or ponds with diverse habitats nearby. Appendix A lists all of the aquatic species collected at the base.

Permanent ponds at the base have aquatic fauna dominated by chironomids and oligochaete worms. Typically, chironomids and oligochaetes are found in fine-grained sediments in streams, rivers, ponds, and lakes throughout the world. The crustacean *H. azteca*, a cosmopolitan species found throughout North America, was very common on rocky substratum in Piute Pond. No endangered or threatened species of macroinvertebrates were found. The base does not support large numbers of immature caddis flies or mayflies, which are commonly found in permanent lentic waters throughout North America. However, caddis flies in the genus *Oxyethira* colonize the surfaces of cattails in Branch Pond. They probably do not colonize the cattails of Piute Ponds due to the higher salinites existing there. Only a few species of snails and no freshwater mussels were found, probably because of the low calcium content of the water and the restricted aspect of these habitats in the immediate area.

Terrestrial vegetation around the permanent ponds, consisting of trees and shrubs, is important in the life cycle of many Chironomidae. When these organisms emerge from the aquatic pupal stage, the adults typically rest for a short period of time on leaves or stems of plants. Vegetation surrounding the ponds provides protection from hot, drying winds. In addition, trees and shrubs serve as markers for swarming of adults immediately prior to mating (Downes 1969; LeSage and Harrison 1980). This terrestrial vegetation should be protected to increase the overall value of the aquatic habitat.

Cattails and algae greatly improve habitat for aquatic organisms in permanent ponds. Aquatic plants provide protection and substratum for attachment by snails, chironomids, and one genus of caddis fly. Any submersed structures (trees, brush, rock) that could be placed in permanent ponds would improve habitat for aquatic organisms.

All of the aquatic species in permanent ponds are a food source for small fishes. In addition, wading and shore birds feed on chironomids and oligochaetes in the sediments, as well as on snails and the amphipod *H. azteca.*

Several amphibians have been reported from the permanent and temporary ponds at Edwards Air Force Base. Piute Ponds and the smaller Branch Pond provide the necessary habitat and food sources for the African clawed frog (*Xenopus laevis*) and bullfrog (*Rana catesbeiana*). Both of these amphibians are aquatic in larval form and require permanent water bodies in which to live. The African clawed frog spends its entire life in the water, whereas the bullfrog spends its larval form in the water and moves onto the land as an adult to forage for food.

Other amphibians reportedly found at the base, the red-spotted toad (*Bufo punctatus*) and the pacific treefrog (*Hyla regilla*), are more terrestrially oriented as adults and spend more time away from the water, but still require water for breeding. The red-spotted toad is a burrower and seems to prefer rocky-bottomed habitat where it can find shelter to spend much of the day since it is nocturnal. The pacific treefrog is more cosmopolitan and tends be found in woodlands, meadows, and pastures on low-lying plants. These two amphibians use temporary water bodies to breed and lay eggs. This gives them the advantage of avoiding predators that require permanent water bodies.

Tadpoles of these species eat suspended matter such as algae, pond plants, and organic debris. The adults feed on a variety of recently emerged insects from permanent and temporary water bodies such as chironomids and other dipterans, as well as adult dragonflies (Odonata) and caddisflies (Trichoptera). Obviously any of the terrestrial insects such as butterflies, beetles, and true bugs that use vegetation surrounding the ponds for food and cover are likely prey items for amphibians at the base.

The results of terrestrial surveys indicated that four insect groups were collected (Diptera, Trichoptera, Odonata, and Ephemeroptera) that have immature aquatic stages and are terrestrial as adults. Diptera (true flies), Trichoptera (caddis flies), and Odonata (dragonflies and damselflies) were all collected in the aquatic sampling. Ephemeroptera (mayflies) were not collected during the aquatic sampling. Mayflies may have been present in some water bodies (such as the small ponds near Piute Ponds), which were not sampled during the aquatic survey. Some members of the Chironomidae (Diptera) have short life cycles; their immature forms could survive in ephemeral as well as permanent ponds.

Adult mayflies, caddis flies, and backswimmers, all of which have aquatic stages, were collected several miles from permanent water bodies during the terrestrial study. Adults of these three insect groups have wings as adults and are capable of flight. High winds are likely to have also aided in distributing aquatic insects during their aerial phase among water bodies.

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Appendix A
Aquatic Macroinvertebrates Collected at Edwards Air Force Base, California, October 1995, March 1996, and May 1996

Table A1
Percent Abundance of Macroinvertebrates Collected Using Quantitative Methods, Edwards Air Force Base, October 1995

Species	Plute Pond		Pond by Sewage Lagoon	Branch Pond
	Near Island	Near Middle		
Diptera				
Chaoboridae				
Chaoborus sp.				8.22
Chironomidae	1.33	7.29		
Tanypodinae				
Tanypodini				
Tanypus nr. grodhausi	0.34	0.50		
Tanypus stellatus				20.55
Macropelopiini				
Procladius (Holotanypus)	0.01	0.54		27.40
Chironominae				
Early instars				1.37
Chironomini				
Chironomus sp.	0.25	0.97		6.85
Hemiptera				
Corixidae				
Larvae	0.05	0.04		
Corisella sp.	0.11			
Notonectidae				
Larvae	0.01	0.04		
Buenoa sp.	0.01			
Odonata (Zygoptera)				
Coenagrionidae				
Larvae				1.37
Oligochaetae	57.09	72.65		
Naididae				
Dero sp.		0.43		
Dero digitata	0.38			4.11
Tubificidae				
Immature w/o cap. chaetae	4.23	4.74		
Limnodrilus sp.		6.60		
Limnodrilus hoffmeisteri	1.60	2.01		
Potamothrix bavaricus	2.63	3.59		8.22
Hirudinea				
Glossophoniidae				
Immature				1.37
Helobdella stagnalis	1.94	0.47		
Amphipoda				
Talitridae				
Hyalella azteca	27.16	0.11		1.37
Cladocera				
Immature				5.48
Daphnidae	0.92			
Copepoda				
Cyclopoid				8.22
Harpactoid	1.95	0.04		5.48
Total Percent	100	100		100

Table A2
Percent Abundance of Macroinvertebrates Collected Using Qualitative Methods, Edwards Air Force Base, October 1995

Species	Plute Pond			Pond near Sewage Lagoon Dip Net	Branch Pond	
	Cattails	Algal Mat	Rocks		Cattails	Dip Net
Coleoptera						
Dytiscidae						
Larvae	0.15					
Heteroceridae						
Heterocerus sp.	0.08					
Hydrophilidae						
Immature		0.10				
Hydrochidae						
Hydrochus sp.		0.10				
Collembola						
Immature	0.08	1.81				
Hypogastruridae						
Immature			0.08			
Diptera						
Pupae	0.08					1.02
Ceratopogonidae						
Pupae		0.10				
Culicoides sp.		0.10				
Chironomidae					4.35	
Pupae	0.69					
Chironominae						
Early instars			1.57			
Chironomini						
Chironomus sp.			0.08			
Glyptotendipes species gr. A			7.28			
Orthocladinae						
Cricotopus sylvestris gr.					4.35	
Tipulidae						
pupae						2.04
Hemiptera						
Larvae			0.08	8.33		1.02
Corixidae						
Larvae		0.30		91.67		
Corisella sp.	20.63					
Notonectidae						
Notonecta sp.	0.53					
Salidae						
Immature	0.08					
Odonata (Anisoptera)						
Aeschnidae						
Immature						18.37
Anax sp.	0.23					
Libellulidae						
Larvae					4.35	22.45
Odonata (Zygoptera)						
Coenagrionidae						
Zoniagrion sp.	0.38					43.88

(Continued)

Table A2 (Concluded)

Species	Piute Pond			Pond near Sewage Lagoon	Branch Pond	
	Cattails	Algal Mat	Rocks	Dip Net	Cattails	Dip Net
Oligochaetae	17.72	15.55			4.35	
Naididae						
Immature			0.08			
Dero digitata						
Nais variabilis					47.83	
Pristina leidyi		4.81				
Tubificidae						
Immature w/o cap. chaetae			0.23			
Trichoptera						
Hydroptilidae						
Oxyethira sp.					4.35	8.16
Hirudinea						
Glossophoniidae						
Immature		0.10	1.49			
Helobdella stagnalis	0.76		5.64			
Amphipoda						
Talitridae						
Hyalella azteca	58.06	76.93	83.40			1.02
Cladocera						
Immature	0.38					
Daphnidae			0.08			
Copepoda						
Calanaoid	0.08					
Cyclopoid		0.10				1.02
Gastropoda						
Physidae						
Immature	0.08				21.74	1.02
Turbellaria						
Planariidae						
Dugesia tigrina					8.70	
Total Percent	100	100	100	100	100	100

Table A3
Percent Abundance of Macroinvertebrates Collected Using Quantitative Methods, Edwards Air Force Base, March, 1996

Species	Piute Pond		Pond by Sewage Lagoon	Branch Pond	Scout Road
	Near Island	Near Middle			
Collembola					
Immature	0.11				
Diptera					
Larvae			0.18		
Pupae		0.10			
Ceratopogonidae					
Larvae			0.18		
Chaoboridae					
Chaoborus sp.				0.43	
Chironomidae	30.94	14.33	94.23	63.79	
Pupae		0.48	0.54	1.29	
Chironominae					
Early instars		0.10			
Chironomini					
Chironomus sp.		0.19			
Hemiptera					
Corixidae					
Larvae		0.10	1.08		
Oligochaetae	61.44	49.47		34.05	
Hirudinea					
Glossophoniidae					
Helobdella stagnalis	0.77				
Amphipoda					
Talitridae					
Hyalella azteca	6.52	34.48			
Cladocera					
Immature		0.48			
Daphnidae	0.22		0.18		
Copepoda					
Calanaoid					
Cyclopoid		0.29		0.43	
Ostracoda					
Immature			3.60		
Total Percent	100	100	100	100	

Table A4
Percent Abundance of Macroinvertebrates Collected Using Qualitative Methods, Edwards Air Force Base, March 1996

	Piute Pond		Pond Near Sewage Lagoon	Branch Pond		Scout Road (Ephemeral)	Branch Memorial Road Ponds				Ephemeral Ponds	
Species	**Dip Net**	**Cattails**	**Dip Net**	**Dip Net**	**Cattails**	**Dip Net**	**0.3 mile Dip Net**	**0.45 mile Dip Net**	**1.1 mile Dip Net**	**1.6 mile Dip Net**	**0.45 mile Sediment**	**1.1 miles Sediment**
Coleoptera											1.00	
Carabidae				25.00								
Dytiscidae												
Larvae			0.34									
Diptera												
Pupae												
Ceratopogonidae												
Larvae			0.34									
Chaoboridae												
Chaoborus sp.				25.00								
Chironomidae	8.33	17.91	55.07				79.17	2.21	2.15	12.50	55.00	
Pupae		0.37	1.35	25.00			0.83				2.00	
Chironominae												
Chironomini												
Chironomus sp.							3.33					
Orthocladinae			0.34									
Ephemeroptera												
Baetidae												
Larvae	0.69											
Hemiptera												
Larvae									0.22			
Corixidae												
Larvae	0.69		31.76								1.00	0.66
Neocorixa sp.			0.68									
Notonectidae												
Buenoa sp.							1.67					
Odonata (Zygoptera)												
Coenagrionidae												
Zoniagrion sp.				25.00								
Oligochaetae	11.11	60.07			100.00							
Hirudinea												
Glossophoniidae												
Helobdella stagnalis		3.73										
Amphipoda												
Talitridae												
Hyalella azteca	78.47	17.54										

(Continued)

Table A4 (Concluded)

Species	Piute Pond		Pond Near Sewage Lagoon	Branch Pond		Scout Road (Ephemeral)	Branch Memorial Road Ponds				Ephemeral Ponds	
	Dip Net	Cattails	Dip Net	Dip Net	Cattails	Dip Net	0.3 mile Dip Net	0.45 mile Dip Net	1.1 mile Dip Net	1.6 mile Dip Net	0.45 mile Sediment	1.1 miles Sediment
Cladocera												
Immature	0.69									12.50		
Daphnidae							0.83	17.13				
Copepoda												
Cylopoid		0.37										
Ostracoda												
Immature			10.14						61.08	50.00		
Anostraca												
Branchinectidae												
Branchinecta sp.						32.61	14.17	77.35	35.05		41.00	99.00
Conchostraca												
Caenestheridae												
Caenestheriella sp						44.57						
Notostraca												
Lepidurus sp.						22.83		3.31	1.51	25.00		0.33
Total Percent	100	100	100	100	100	100	100	100	100	100	100	100

Table A5
Percent Abundance of Macroinvertebrates Collected Using Quantitative Methods, Edwards Air Force Base, May, 1996

Species	Piute Pond		Sewage Treatment Plant Pond	Branch Pond	Scout Road
	Near Shore	Near Middle			
Diptera	2.24	2.39	0.80	1.18	
Chaoboridae					
Chaoborus sp.				4.71	
Chironomidae	37.01	42.08	94.42	89.41	20.00
Hemiptera					
Larvae	0.30	0.87	4.78		
Oligochaetae	51.94	49.02		4.71	
Hirudinea	1.34	0.87			
Amphipoda	5.52	4.34			
Cladocera	0.60	0.43			
Copepoda	1.04				
Anostraca					80.00
Total Percent	100	100	100	100	100

Table A6
Percent Abundance of Macroinvertebrates Collected Using Qualitative Methods, Edwards Air Force Base, May 1996

Species	Piute Pond			Pond by Sewage Lagoon	Branch Pond		Scout Road
	Dip Net	Algal Mat	Rock		Dip Net	Cattails	
Diptera					0.74		
Chironomidae	6.67	46.21	75.45				
Hemiptera							
Larvae	21.67			100.00			8.92
Odonata (Anisoptera)					1.11	1.28	
Oligochaetae		6.06			94.07	89.74	
Trichoptera							
Larvae					0.74	1.28	
Hirudinea							
Immature			1.80				
Amphipoda	50.00	47.73	22.75				
Cladocera							
Immature	18.33						
Copepoda					0.37		
Gastropoda					2.96		
Immature	3.33						
Anostraca						7.69	91.08
Total Percent	100	100	100	100	100	100	100

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13. ABSTRACT *(Maximum 200 words)*

Quantitative (Petite Ponar sampler) and qualitative methods (dip net, collection by hand of aquatic plants and algae for attached macroinvertebrates) were used to sample aquatic habitats at Edwards Air Force Base in the Mojave Desert, California, in October 1995, March 1996, and May 1996. The area that supported the greatest number of aquatic macroinvertebrates was Piute Pond. Comparatively fewer aquatic species and individuals were present in Branch Pond, which had been drained and dredged 4 months prior to the start of the survey. A pond near a sewage lagoon was virtually void of aquatic organisms. Ephemeral ponds or clay pans at the base supported mainly crustaceans (including tadpole, clam, and fairy shrimp), and some immature flies (chironomids). Overall, the macroinvertebrate fauna at the base was dominated by chironomid larvae (immature flies), oligochaete worms, and the amphipod *Hyalella azteca* with fewer numbers of snails and leeches. No federally listed threatened or endangered species were collected. Water bodies at the base do not support large numbers of immature caddisflies and mayflies, which are commonly found in permanent water bodies throughout North America.

(Continued)

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Despite high species richness in the terrestrial community, ponds supported a simple aquatic invertebrate fauna. In Piute Pond (a permanent water body), invertebrate biomass was dominated in October by two ubiquitous species—the amphipod *H. azteca* and the leech *Helobdella stagnalis*. The numerically abundant chironomids and oligochaetes exhibited low species richness and composed but a smaller part of the aquatic biomass. Most of the aquatic taxa on the base were ubiquitous and commonly found throughout North America. In the permanent pond the highest macroinvertebrate density was found in the fall of the year.

Permanent ponds, a rare habitat at the base, were associated with high terrestrial species richness and occurrence of possibly endemic species. Cattails, algae, and other structure greatly improved habitat for aquatic organisms in these ponds. Aquatic habitats are a unique resource at Edwards Air Force Base and provide habitat for organisms that are food for fishes and resident and migratory birds.

Compared with terrestrial habitat, ponds on Edwards Air Force Base are few and relatively simple. However, ponds in the desert are unmistakably special in a landscape context. Only when terrestrial invertebrate reliance on permanent ponds is considered is the special habitat value of ponds revealed. Thus, the habitat value of ponds on Edwards Air Force Base emanates not from an intrinsically rich or rare fauna within them. Rather, these ponds in an arid landscape add productivity, diversity, and complexity that support a rich and possibly rare terrestrial invertebrate fauna that otherwise could not exist.